Smart grid solutions in the everyday life of households

Electric vehicles and time-of-use pricing

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This report presents the outcome of work package 3 SMART GRID SOLUTIONS IN EVERYDAY LIFE SETTINGS of the ERA-Net SmartGrids project "Integrating households in the smart grid" (IHSMAG)

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1. Introduction

This report is an outcome of work package 3 “Smart grid solutions in everyday life settings” of the project *Integrating Households in the Smart Grid* (IHSMAG), which involved partners from Norway, Denmark and the Basque Country (Spain). The aim of IHSMAG was to contribute with knowledge on how to develop comprehensive designs of smart grid solutions that involve households in the smart grid.[1]

The aim of WP3 was to contribute to a better understanding of the interplay between smart grid solutions and the daily electricity-consuming practices of households, including transport practices. As demand-side management (flexible energy demand) has become one of the core objectives in smart grid development and visions, WP3 focused especially on the connection between the temporal organisation of households’ everyday practices and the timing of the residential electricity consumption – and how smart grid solutions influence the temporal patterns of practices and electricity consumption. In addition, the study also analysed how families integrate electric vehicles (EVs) in their everyday life and hence includes analysis of mobility intervention strategies associated with the dissemination and adoption of EVs.

Theoretically, the WP3 study was anchored within social practice theories, but it has also included other theoretical approaches. Empirically, the study draws mainly on in-depth qualitative interviews and focus groups with households participating in the EV demonstration project *Test an electric vehicle* (“Test en Elbil”) and the static time-of-use pricing trial called *Dynamic Network Tariff* (“Dynamisk Nettarif”). In addition, the study also included participant observations as well as statistical analysis of hourly-based recordings of the electricity consumption of households participating in the *Dynamic Network Tariff* demo.

WP3 was carried out in collaboration with the electricity provider and DSO *SE* (leading the *Dynamic Network Tariff* demo) and *Clever* (leading the *Test an EV* demo).

The findings of WP3 are reported in a number of publications (several peer-reviewed), which are listed at the end of this chapter. In this report, we provide an overview of the background and theoretical approach of the study, the research design and methods as well as the analytical findings and conclusions. It has not been the aim to provide an exhaustive presentation of the project activities and results in this report, as this has already been done in previous publications and the PhD Thesis (Friis, 2016), which was the core activity of the work package. Instead, the aim is to provide an overall description of the outcome of the study.

The findings from WP3 have – along with the other IHSMAG work packages – also contributed to the design recommendations for technology developers, grid operators, policy makers and others presented in the report *Recommendations and criteria for the design of smart grid solutions for households* (Christensen et al., 2016).

[1] For more information about the IHSMAG project, see the website: www.ihsmag.eu

Publications related to WP3

Christensen, Toke Haunstrup (2014): "The role of learning and social interaction for changing practices". Paper for the workshop "A Social Practice Perspective on the Smart Grid" at the *ICT for Sustainability, ICT4S 2014 Conference*, 24-27 August 2014, Stockholm, Sweden.

Christensen, Toke Haunstrup; Friis, Freja (2016): “Materiality and automation of household practices: Experiences from a Danish time shifting trial”. Paper for the *DEMAND Centre Conference*, 13-15 April 2016, Lancaster, UK.

Christensen, Toke Haunstrup: Gram-Hanssen, Kirsten; Friis, Freja (2012): ”Households in the smart grid – existing knowledge and new approaches”. Paper for the *2nd Nordic Conference on Consumer Research*, 30 May – 1 June 2012, Göteborg, Sweden.

Christensen, Toke Haunstrup; Gram-Hanssen, Kirsten; Friis, Freja (2013): “Households in the smart grid – existing knowledge and new approaches”. In: Hansson, L., Holmberg, U., Brembeck, H. (Eds.) *Making Sense of Consumption. Selections from the 2nd Nordic Conference on Consumer Research 2012*, p. 333-348. Göteborg: University of Gothenburg.

Friis, Freja (2016): “Integrating smart grid solutions within everyday life: A study of household practices in relation electric vehicles and time-of-use pricing”. PhD Thesis. Copenhagen: Danish Building Research Institute, Aalborg University.

Friis, Freja (submitted): “Making sense of electric vehicle driving: Examining interventions in mobility practices”.

Friis, Freja; Gram-Hanssen, Kirsten (2013): "Integration of smart grid technologies in households – how electric vehicles and dynamic pricing change social practices in everyday life." *ECEEE 2013 Summer Study*, 3-8 June 2013, Belambra Presqu’île de Giens, France.

Friis, Freja; Christensen, Toke Haunstrup (2016): “The challenge of time shifting energy demand practices: Insights from Denmark”. *Energy Research & Social Science* Forthcoming.

2. Theoretical approach

The theoretical outset of the WP3 study is “social practice theories”. Practice theories are not a new or common agreed upon, unified theory, but rather an approach or “turn” in sociological thinking (Gram-Hanssen, 2011; Schatzki et al., 2001). The idea of social practices being the analytical unit for exploring the social was (re-)introduced within the social sciences by Theodore Schatzki and Andreas Reckwitz (Schatzki, 1996; Reckwitz, 2002). Both re-interpreted and synthesized theoretical elements based on work from sociologists and philosophers such as Giddens (1984), Bourdieu (1990), Butler (1990), Foucault (1978) and Latour (1993).

To get an overview, Halkier & Jensen (2008) divide the range of practice-aligned approaches into two positions. On one side, the scholars who attempt to systematise and position social practice theories on a general theoretical level by distinguishing it from other sociological theories (e.g. Reckwitz, 2002; Schatzki, 1996; Schatzki et al. 2001). On the other side, the more operational and empirically based approaches, particularly within the area of consumption research (e.g. Shove & Pantzar, 2005; Shove et al., 2007; Warde, 2005), environmental and sustainability research (e.g. Burgess et al., 2003; Shove, 2003; Southerton et al., 2004; Spaargaren & Van Vliet, 2000) and in socio-technological research (e.g. Christensen & Røpke, 2005). Further, recent contributions also attempt to meet the critical challenges of sustainable change by integrating elements from system-based transition theories. Contributions to developing such “system of practices” approaches include Watson (2012), Spurling and McMeekin (2014), and Shove et al. (2015).

The practice theories approach seeks to overcome the structure-actor dualism regarding whether human behaviour is primarily determined by social structures or individual agency. Practices are not viewed as individual acts, but rather as collective actions where the individual can be viewed as a carrier (Reckwitz, 2002). This understanding of practitioners as “carriers of practices” can be aligned with the concept of “habitus” from Bourdieu (1998). Habitus describes the embodiment of practices and dispositions and thus explains why we tend unconsciously to repeat structures and collective practices based on what we have learned and been exposed to during our lifetime, from childhood to adulthood.

Another important observation from practice theories is that consumption of energy (and resources in more general terms) is the *outcome* of performing practices. As Alan Warde observes: “(…) consumption is not itself a practice but is, rather, a moment in almost every practice.” (Warde, 2005:137). Thus, everyday practices like cleaning, preparing food, doing the dishes, washing clothes, commuting and many entertainment activities (like watching television) all involve some form of energy consumption. Consequently, the timing of energy consumption (*when* energy is used) is closely tied to the temporality associated with the performance of practices (as is also explored in this study).

As an effect of the heterogeneous approaches within theories of practice, the elements configuring social practices have been variously interpreted (Gram-Hanssen, 2011). Schatzki defines a practice as a “temporally unfolding and spatially dispersed nexus of doings and sayings” hold together by three elements: 1) shared understandings, 2) explicit rules and 3) teleo-affective structures (the latter is described as the "ends, projects and tasks" associated with moods and emotions) (Schatzki, 1996:80,89). These blocks or patterns of activity are filled out and enacted by practitioners that through their performances of doings reproduce, transform and perpetuate the practices they carry. Reckwitz (2002) defines a practice as "a routinized type of behaviour, which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge" (Reckwitz, 2002:249).

Shove and Pantzar (2005) simplify the number of elements constituting practices to three elements: competences, meanings and products. Shove et al. (2012) write that "practices are defined by interdependent relations between materials, competences and meanings" (Shove et al., 2012:24). The elements are further specified as: "(…) 'materials' – including things, technologies, tangible physical entities, and the stuff of which objects are made; 'competences': which encompass skill[s], know-how and technique; and 'meanings': including symbolic meanings, ideas and aspirations." (Shove et al., 2012:14). Using driving as an example of an energy-consuming practice, this practice entails some physical "materials" (e.g. the car, but also the material infrastructure), "competences" (e.g. the embodied competences and skills of driving) and "meanings" (e.g. understandings of driving as associated with freedom or necessity). Through the performance of driving, the practitioners (the "drivers") activate and perform different links between these elements and in this way reproduce and change the dynamics of the collectively shared driving practice (Shove et al., 2012:8).

The conceptualization of the elements originally developed by Shove and Pantzar (2005) has proven useful in many empirical studies. However, the same can be said about the conceptualization developed by Gram-Hanssen (2011), who distinguishes between four different types of elements: Know-how and embodied habits (unconscious and embodied habits and routines, e.g. learned through childhood), institutionalized knowledge and explicit rules (including e.g. technical knowledge and information provided through campaigns etc.), engagement (refers to the ends people are seeking to achieve) and technologies (e.g. washing machines, computers, cars etc.) (Gram-Hanssen, 2011). As it can be seen, there are many similarities between the conceptualizations of elements by Gram-Hanssen and Shove & Pantzar, except that Gram-Hanssen distinguishes explicitly between know-how/embodied habits and institutionalized knowledge/explicit rules, which Shove & Pantzar combines in the element of competences.

Across the different conceptualisations of practices and their constituting elements, it is in particular the emphasis of including material elements in our understanding of how social practices are produced and reproduced that makes social practice theories different from other social and cultural theories. The emphasis of the material as a significant dimension in practices to a high degree reflect the impetus from the Actor Network Theory tradition (with Latour, Akrich and Callon among the influential contributors).

Overall, social practice theories depart from the dominating human-centred psychological and economic theories often applied within consumption and (environmental) behaviour studies. Shove (2010) has termed these dominating theories the "Attitudes, Behaviour, Choice" (ABC) model. The dominant ABC paradigm relates to the typically restricted modes and concepts of social change embedded in contemporary, established policy approaches, which primarily frames human action as a matter of individual choices and an outcome of individual attitudes. Through confronting and criticising the limitations of this assumption and its lack of success in obtaining long-lasting transformations and reductions in energy consumption, social practice theories are positioned as an alternative approach to inform intervention and sustainable transition (Hargreaves, 2011; Shove, 2010; Shove et al., 2012; Strengers & Maller, 2014; Watson, 2012).

How (consumption and energy within) practices are reconfigured and changed over time and space is a theme for continuous discussion and exploration within practice theories. Reflecting the energy transition and smart grid discussion, practice theorists underpin that households are more than consumers, and thus rather should be considered as "practitioners" or co-managers who are implicated in the routine functioning of the system as a whole (Shove & Chappells, 2001:57). Thus, sustainable consumption interventions and smart grid development have to recognise that innovation should be embedded in the daily life (Shove et al., 2007).

The discussion of how practices are reconfigured and changed over time and space has become a central theme within more recent practice theoretical studies. Some of these have been inspired by the Multi-Level Perspective (MLP) developed by Geels (2010) and have attempted to argue of valuable potentials of intersections and crossovers between social practice theory and MLP (Gram-Hanssen, 2011; Hargreaves et al. 2013; McMeekin & Southerton, 2012). For instance, Hargreaves et al. argued through empirical analysis of two different case studies of sustainability innovation that "intersection between regimes and practices offers vital insights into processes that can serve to hinder (or potentially help) sustainability transitions" (Hargreaves et al., 2013:403). Their conceptual framework does not suggest an integration of the individual, distinctive strengths of practice theory and MLP, but rather to retain the distinction between regimes and practices and explore how they intersect.

Another dimension related to change of practices and governance is the role of power and power relations. Thus, on basis of the empirical example of resource-intensive personal mobility, Watson (2012) argues that current patterns of mobility are constituted and reproduced by travellers' practice performances, but also embedded in systems of power and interest. These aspects related to power and governance, and how this relates to continuity and change of practices over time, has also been one of the key interests for the WP3 study.

3. Method

In this section, we will first describe the two demonstration projects that were studied in WP3 (Test-an-EV and Dynamic Network Tariff). Then follows a presentation of the research design and methods applied in relation to the studies of the two demonstration projects.

3.1 The demonstration projects

3.1.1 Test-an-EV (TEV)

The Test-an-EV (TEV) demonstration was carried out by the Danish mobility operator Clever (partner in the IHSMAG project), and the aim was to gather knowledge and experience about EV-driving by testing first generation mass-produced electric vehicles (EVs) among 1578 households living in different parts of Denmark. Typically, each household (family) would borrow the EV for a three months period. It was a requirement that the households should already own a (conventional) car in order to be eligible to participate in the demonstration project. In this way, in most cases the EV would become the household's second car. The EVs included different models from Mitsubishi (iMiev), Peugeot (Ion), Citroën (C-Zero) and Nissan (LEAF).

TEV was framed as the greatest and most ambitious EV demonstration project in Northern Europe. From 2011 to 2014, 198 EVs were tested in 24 Danish municipalities. The demonstration project delivered a variety of "hard" data from data loggers installed in the cars and "soft" data from the test drivers' experiences about EV driving reported in "driving books" and by weekly web-logging.

Overall, the project has provided the company Clever with knowledge about the operational reliability, charging patterns and driving needs related to use of EVs. In addition, the project provided in-depth knowledge on the energy potential of the state-of-art EVs and challenges for further operation. Part of the goal of the demonstration project was to test the difference between two ways of performing the EV battery charging; manual load management and automated load management controlled by the operator.

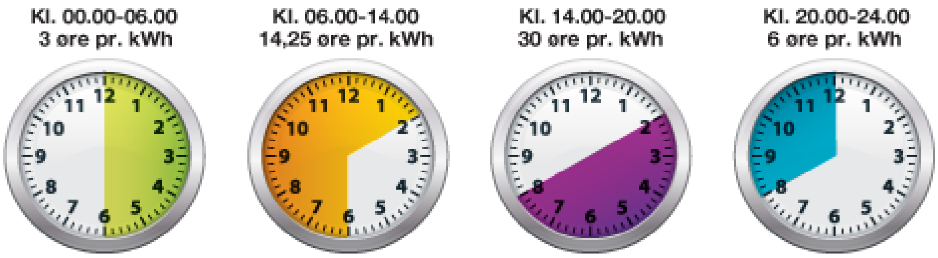
Besides Clever's own funding and sponsorships from private companies, the demonstration project got public funding from the Danish Transport Authority, the Danish Energy Agency and several municipalities. Owned by five

Danish utility companies, Clever's overall business strategy is to install smart equipment to manage users' electricity consumption and save the grid for critical peak loads. Hence, the comprehensive data collection of the test-driving was basically used to develop the company's future business and operation strategy to improve the smart grid potential of EVs in Denmark (Clever's final report, 2014; interviews with the operator conducted in 2013). In parallel with the implementation of the demo project, Clever opened a nation-wide network of EV charging stations in 2012.

3.1.2 Dynamic Network Tariff (DNT)

A small number of the "test drivers" of the Test-an-EV demonstration additionally participated in another smart grid demonstration implemented by the electricity supplier and distribution system operator SE (South Energy) aiming to test how dynamic network tariffs influence consumers' everyday consumption patterns. This demonstration project was named Dynamic Network Tariff (DNT).

The DNT trial offered 18 test drivers variable network tariffs and static time-of-use pricing (Darby & McKenna, 2012) for the network tariff. For instance, the network tariff was ten times cheaper during the night hours 0-6 (0.4 euro cent/kWh) than in the peak hours 14-20 (4 euro cent/kWh).



Together with the market electricity price and taxes, the total electricity price for Danish household customers is about 0.3 euro/kWh. Thus, the maximum variation in the network tariff represents about 15% of the total electricity price and hence represents a relatively weak price signal. In addition to DNT, the participants also had a spot price agreement, which is a real-time pricing scheme (Darby & McKenna, 2012) following the hour-by-hour market price of electricity on the Nordic *Nord Pool* spot market. The average market price was about 4-5 euro cent/kWh. However, the interviews with the households showed that none of them adopted the real-time pricing scheme as they experienced the hour-by-hour and day-by-day changes in electricity prices too complicated to follow and integrate with their daily energy-consuming practices.

The combined TEV and DNT trial aimed to test the impact of economic incentives on households' flexibility to time shift their electricity consumption to hours with low electricity demand in order to avoid peak load. Like Clever, SE presumed that the participants' incentive to consume electricity during the most affordable hours of the day would increase by participating in two smart grid trials at the same time. In particular, the consumption patterns were expected to change in relation to dishwashing, laundry activities and EV charging.

The DNT ran from April to November 2012, while the combined DNT and TEV trial ran from May to October 2012 (thus, the 18 participants in the combined trial were offered six months participation in TEV instead of just three months like the other test drivers). None of the households participating in both DNT and TEV had electric heat pumps or PVs, which was the criteria set by the project owners to avoid confusion related to the interpretation of the consumption data.

As part of the trial, Clever wanted to test the difference between two ways of performing the EV battery charging; manual load management and automated load management controlled by the operator. The shift from manual to automated load management was implemented in September 2012.

The households participating in the combined trial lived in detached houses in suburban areas of the middle-sized cities Aabenraa and Sønderborg situated in the South of Jutland, which is characterised by being an economically declining region of Denmark.

3.2 Research design and methods

The overall objective of the WP3 study has been to expand our understanding of the complexity of factors in the everyday life influencing the success of smart grid initiatives for households. The theoretical approach has been inspired by practice theories, and as part of this, a particular focus has been on the status and role of materiality and technical designs in shaping (new) social practices of the families and the possible implications of this for the energy consumption.

The empirical study draw on a mixed-methods approach combining different methods in order to contribute with multi-faceted descriptions of the cases and the experiences of the households with the DNT and TEV demonstrations. The main empirical methods applied were semi-structured qualitative interviews and focus groups. In addition, the study also includes participant observation, analysis of the test drivers self-reporting via weblogging and field notes as well as quantitative data in form of a statistical analysis of the hourly-recorded metering data of the electricity consumption of the households participating in the combined trial. In the following, we will provide a more detailed description of each of these methods.

3.2.1 Semi-structured qualitative interviews

Eight of the 18 participants in the combined DNT and TEV trial took part in individual, semi-structured interviews (Kvale, 1996). The aim of these interviews was to provide insight into the everyday perspectives of the households. The interviews were carried out during the summer of 2012.

The underlying basis for the selection of interviewees (as well as focus group participants) was to get the highest possible variation on variables such as gender, age, income, marital status, household size, number of children living at home, description of motivation in the application (to Clever/TEV) and driving needs (km). The assumption was that diversity would contribute to a more comprehensive understanding of the complex nature of households' interaction with the EV technology and static time-of-use pricing. All households were living in detached houses with a garden and a garage.

The goal of the interviews was to achieve knowledge about the interaction between the two smart grid projects TEV and DNT and the everyday social practices of the households; to explore how the trials influenced on households' habits and routines and vice versa. The approach was aimed to be as open-minded and inductive as possible, even though the interviews will always be a co-construction between the interviewer and the interviewee. The design of the interview guide and the approach were inspired by Kvale's thoughts on the semi-structured qualitative interview (Kvale, 1996) and Spradley's descriptive questioning techniques (Spradley, 1979).

The interview guide was semi-structured and thus designed to follow different topics/themes around challenges and advantages related to the participants' temporal rescheduling of their consumption patterns and re-organizing of their driving activities. Though most of the interviewees only involved the person who had originally applied for participation in the TEV, the interviews also aimed at giving insight into the relationships within the households and to cover other household members' experiences and perceptions. The interviews were carried out at the home of the interviewees and lasted 1-2 hours. See Table 1 for more details.

Table 1: Details about the interviewed test drivers (combined trial)

Participants*	**Anne-Mette**	**Søren**	**Ebbe**	**Hans**	**Mia**	**Viola**	**Hannah**	**Nicolas**
Age and gender	61, f*	42, m*	51, m	45, m	33, f	32,f	48, f	36, m
Household size	2	4	3	2	2	4	2	4
Children	0	2h*, 1o*	1h, 2o	1h	0	2h	1h, 3o	2h
Daily transport needs(km)	40-60	20-40	60-70	60-70	20-40	20-40	0-20	40-60

* participants' names are changed to ensure anonymity; f indicates female and m indicates male; h indicates the number of children living at home; o indicates children no longer living at home.

The transcribed interviews were later coded in order to organize the material into analytical themes and observations. Due to the abductive research approach, the different analytical themes occurred during the process of coding afterwards.

In addition to the interviews, semi-structured interviews were also done with the managers from Clever and the funder from the Ministry, primarily focusing on their roles as "change agents" (Strengers, 2012). The interview guides for these interviews focused on aims, strategies, challenges, advantages and future interventions related to mobility operation. In particular, the interviews with the project leader and project coordinator from Clever, respectively, attempted to illuminate their experiences related to operationalizing the demonstration project. The interview with the funder attempted to achieve knowledge about overall assumptions of how to reach the goals for decarbonizing the transportation sector, how TEV was a strategical measure to reach that, the background for funding the demonstration project, expected outputs and what the funder so far had experienced as core challenges and advantages related to TEV.

3.2.2 Focus groups

Three focus groups with participants living in the suburbs north of Copenhagen were carried out in the winter of 2013. Focus groups are suitable of exploring how "meaning" is constructed in the social interaction between people (Halkier, 2010; Morgan, 1997). The moderator of focus groups aims to stimulate the participants' reflections in relation to a specific topic, in this case the sense making related to EV driving. As part of this, the aim of the focus groups was to discover normative negotiations and positions revealed in the discussions. The focus group discussion centred on a number of themes about meaning related to driving in general, participation in the demonstration, EV driving, adoption, charging behaviour, sharing experiences etc.

The participants in all three focus groups were very eager to discuss and reflect about the sense making of EV driving. The participants were very open about what they found bad and good about EV driving. The discussions in the focus groups underpinned the findings in the individual interviews about "the good life" as coupled with powerful comprehensions of freedom, flexibility and individuality determined by conventional driving.

Table 2 shows details about the test drivers participating in the focus groups.

Table 2: Details about the participants in the focus groups

	Focus group 1			Focus group 2		Focus group 3		
Participants*	Cevin	Bella	Max	Maya	Lily	Mark	Mia	Jacob
Age and gender	53, m*	45, f	33, m	35, f	43, f	54, m	34, f	59, m
Households size	1	4	4	4	4	3	4	2
Children	0	1h*, 1o*	2h	2h	2h	1h, 1o	2h	3o
Daily transport needs (km)	40-60	60-70	40-60	60-70	60-70	20-40	20-40	0-20

* participants' names are changed to ensure anonymity; m indicates male and f indicates female; h indicates the number of children living at home; o indicates children no longer living at home.

3.2.3 Participant observation, blogging and field notes

In addition to qualitative interviews and focus groups, the WP3 study also builds upon qualitative data from participant observation, field notes and the TEV participants' weblogging about their personal experiences. The participant observations were in particular made in relation to the information and mid-term meetings of the trials. The purpose was to observe the operator's framing of the project, to observe the expectations among the participants and the operators and to discover the operator's strategic tools of ensuring engagement among the trial participants and commit them to follow the trial scripts and concepts during the test period.

As an important part of the TEV trial, the participants were obliged to blog on a weekly basis about their experiences and feelings related to be a "test driver". The blog entries were included as a part of the empirical material.

Finally, field notes summing up the experiences from the interviews (including observations about atmosphere, noises, the spatial and material organization of the home etc.) were written right after each qualitative interview with the trial participants. Similar notes were prepared after each focus group.

3.2.4 Quantitative analysis of metering data

In addition to the qualitative methods described above, a quantitative (statistical) analysis was also carried out of the hourly-recorded metering data (delivered by SE) from DNT. On basis of these data, load profiles were developed (both for all participants in DNT and for the sub-sample of households participating both in DNT and TEV). In order to avoid summer and autumn holidays, July, August and October were excluded. Also, May were excluded from the analysis because of start-up problems in the beginning of the TEV trial. Thus, the statistical analysis focuses only on the load profiles of June and September (comparing 2011, 2012 and 2013).

The DNT trial included 184 customers (hereof, 18 customers also participated in TEV). For the purpose of the statistical analysis, meter installations related to farms, second homes or customers within retail or education were excluded from the sample due to the assumption of these having quite different load profiles compared with family homes. This reduced the sample size to 171. Furthermore, households with a negative annual consumption in 2013, which indicates that they had installed PVs after the end of the trials, were also excluded as well as a few customers with insufficient data due to metering fails. This limited the final sample to 159 households, which was divided into three groups (Table 3).

Table 3: Three categories of households in DNT sample. Note: None of the households participating in both DNT and TEV had electric heating/heat pumps or PVs.

Type (sub-sample)	**Number**	**Share of sample (%)**
Households participating in both DNT + TEV	14	9%
Households participating in DNT (with electric heating/heat pump)	31	19%
Households participating in DNT (without electric heating/heat pump)	114	72%
Total	159	100%

First, the load profile for each meter installation (i.e. household) was normalised in relation to the average hourly electricity consumption for the period (100% = average hourly load) for this meter. Next, the average of the normalised load profiles was calculated for each of the three groups above.

4. Results and analysis

The analysis and findings of this study have been reported in a number of research papers and a thesis (see list of publications in Section 1). In this section, we will summarize the main results and analytical findings (with references to papers).

4.1 Review of smart grid development in Denmark and the role of households

Our introductory literature review and review of Danish smart grid projects involving households (Christensen et al., 2013) shows that the mainstream vision of smart grid design and technology is dominated by an "supply-driven" assumption to accomplish demand-side management through consumers "micro-operation" in relation to consuming, storing and producing electricity depending on the overall requirements of the system.

The majority of Danish smart grid projects and activities targeting households can be divided into two different approaches. The first approach (the dominating) focuses on pure technological solutions controlled by automated and/or remote management of appliances controlled by the electricity companies. This approach includes very little participation of consumers. In opposition, the other approach assumes flexibility to be provided through active participation of consumers motivated by information and electricity prices (time-of-use pricing). For both approaches, however, our analysis highlights the risk for technology-centred designs to reinforce un-intended side effects such as rebound effects. Instead of continuing the dominant techno-rational approach to consumption change, it is proposed that interventions – operators and other core actors – should recognise the configurations and complexities of collective performances of inconspicuous electricity consumption in the everyday life. Hence, the theoretical practice-based orientation was set to guide the following analysis in WP3.

4.2 Integration of smart grid technologies in households – changing everyday practices

The qualitative interviews with households participating in the combined DNT and TEV trials demonstrate how the integration of EVs and time-of-use pricing as new smart grid technologies (solutions) influences the everyday practices of the household members (Friis & Gram-Hanssen, 2013). More specifically, the study shows changes in relation to the participants' driving practices and the timing of their everyday practices more generally.

The new *driving performances* were characterised by test drivers' increased consciousness about the engines' energy use and limitations of the battery capacity, which initiated more environmental-friendly driving techniques. Thus, all interviewees expressed how the EV increases their awareness of driving distances and they were in general aware about the electricity consumption while driving and attempting to drive as "economic" as possible. For instance, one interviewee (Anne-Mette) said:

> Well I'm certainly more aware of where I actually drive and it has surprised me how much you actually drive. The EVs' battery capacity makes you incredible aware of, hey, you have again travelled 100 km. (…) well the air-conditioning is only on if it is really necessary.

Also, some interviewees started to bundle their activities (travel destinations) through coordination and planning in order to reduce the number of kilometres and avoiding running "empty" on the battery. For instance, a businessman developed a new routine of coordinating his different appointments with customers and business partners (in time and space) instead of spreading them over the week. He explained:

> Earlier I just randomly threw meetings in [in the calendar] and now I think 'where do you call from? From Aabenraa! Okay what else do I have to do in that area' (…) during the test period I've become much better to cluster my appointments in specific geographical places. (Nicolas)

The above illustrates how the limitations of the battery capacity essentially helped (forced) the participants to develop more energy efficient driving patterns. However, the interviews also indicate that there might be negative unintended implications of increased use of EVs. Thus, almost all interviewees stated that they used the EV more often in comparison with their conventional car. This was due to different reasons such as the interviewees found it "funny" to test the new car, the pleasure of driving an EV or that it feels easier and cheaper to go for a quick "get-away" in the EV. For instance, one interviewee explains:

> I must say that for these short distances into town, well, then I take the electric car rather than walk as I did before. You don't think as much about saving the car engine, because you don't have the same wear on the electric car, as you have on the other. (…) in a diesel car you better drive some longer distances (…). (Hans)

Also, the notion of EV driving as being more environmentally friendly than driving in combustion engine cars made it feel less worse to take the car also for short trips instead of going by bike or foot.

In addition, the EV trial period also seemed to increase the participants' experience of a need for an extra car (i.e. having two cars). However, this is probably a particularity for the TEV trial, as it was a requirement for the households to have a (conventional) car already before the trial.

With regard to the timing of everyday practices (and their related electricity consumption), the interviews show that many of the households managed to time shift their dishwashing, laundry and EV charging to low-tariff hours in the late evening and night. These findings are elaborated in further detail in the following section (and in the papers (Christensen & Friis, 2016; Friis & Christensen, 2016. Friis & Gram-Hanssen (2013) demonstrate that the interviewed participants' engagement in relation to the static time-of-use pricing (DNT) was strengthen by the combination of the two trials (DNT and TEV) and their related technologies/solution. Thus, an interviewee said:

> If we didn't have a car (EV), the benefits of the Project Dynamic Pricing [DNT] would have been incredibly low. (Nicolas)

Thus, the results indicate that there can be strong benefits (mutual reinforcement) from combining different smart grid technologies and solutions.

By scrutinising the different elements configuring the practices, the WP3 study demonstrates how different links and interrelations between the elements of practices (see Chapter 2) developed new driving performances and new practices of postponing dishwashing, laundry and EV charging. However, rather than explaining the high flexibility as a matter of economic incentives (like the EV operators did), Friis & Gram-Hanssen (2013) emphasise the elements of “institutionalised knowledge and explicit rules” and “engagement” as fundamental for the participants’ new practices.

4.3 Time shifting energy demand practices

In Friis & Christensen (2016), the everyday temporal context and implications of the time-of-use pricing scheme *Dynamic Networking Tariffs* are analysed in detail. Following Southerton (2012), we analyse how the temporality of practices are shaped by the collective and personal temporal rhythms as well as how practices are themselves shaping the collective and personal temporality. More specifically, we study how the time shifting of dishwashing, laundry and EV charging influences the temporal rhythms of the household as well as how the efforts and experiences with time shifting these practices are shaped by the shared temporal rhythms of the households (and the institutionalized rhythms of society on a wider scale).

The analysis showed that the time shifting created new “coupling constraints” (Hägerstrand, 1985) in the everyday life of the households, e.g. loading/unloading the washing and dishwashing machine in the mornings, which challenged household members’ (feeling of) control over the temporal organisation of activities and practices in their daily life. Thus, the mornings can be experienced as more time pressured because of the extra doings to be done in the morning, which also threatens the “family togetherness” around the breakfast table (cherished by the families), as demonstrated by the following quotes from the interview with a 42-year old father (Søren):

> (…) we have … to get up a little earlier or take a shorter shower. And Signe [the daughter] has to find her clothes quicker. In the beginning we consequently finished our mornings too fast, which meant that we were actually ready to leave before time.
>
> Before, we were united here in the kitchen, now it is more like one is outside hanging laundry, while another is inside unloading the dishwasher. We have to hurry up a little extra.

Following Southerton’s concept of “hot spots” and “cold spots” (Southerton, 2012; 2003), the new practices of hanging clothes up in the tightly scheduled mornings (hot spots) challenged the cherished qualities like being together (cold spots) around the breakfast table. Thus, time shifting electricity-consuming activities like dishwashing and laundry to the night hours challenge the existing everyday time-patterns (rhythms) of the households and in this way creates experiences of stress and inconvenience.

On basis of this, we recommend future smart grid interventions to be convenient, reliable, predictable and not too time demanding. Further, the analysis indicates that synchronisation between practices (whenever possible) can be important for households’ engagement in time shifting. Thus, the interviews show that the households relatively easily developed a routine of plugging in the recharging cable before going to bed (as part of the “shutting-down-the-home” routine in late evening).

Considering practices as a “nexus of sayings and doings” (Schatzki, 1996), our research compared the interviewees’ “sayings” about (their own) time shifting with the “doings” as represented in the load profiles developed on basis of the hourly-recorded metering data. This first and foremost confirmed the “sayings” by verifying a new peak during the night hours among the households participating in both DNT and TEV (see Figure 2), which indicates that future demand-side management strategies could benefit from combining interventions.

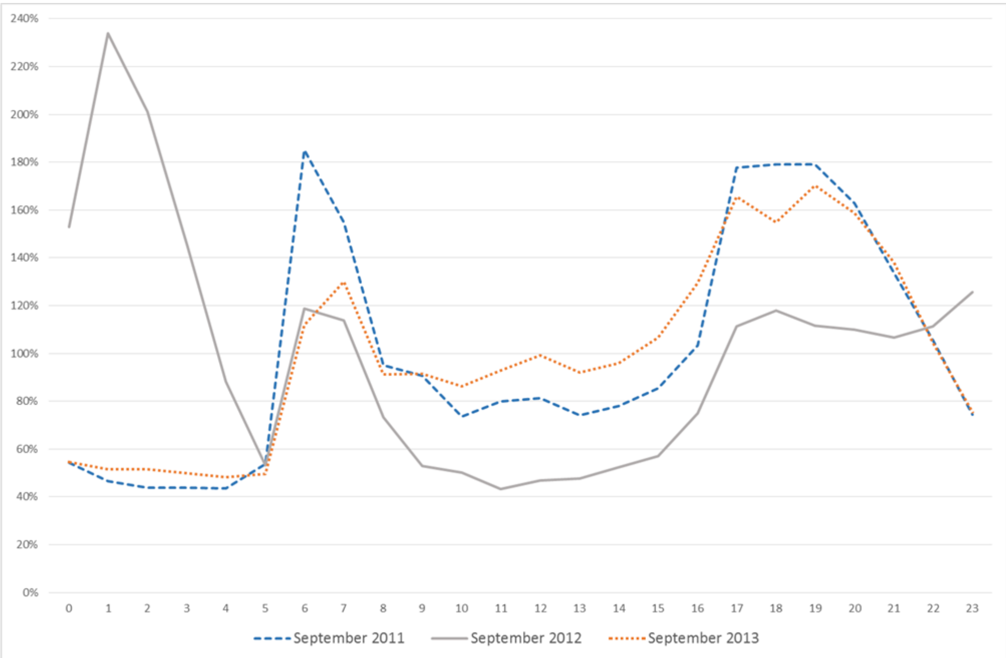


Figure 2: Load profiles of the households with an EV for 2011-2013 for weekdays in June and September. Note: Hours shown on X-axis are in Danish Summer Time. 100% represents the average hourly load of the sample.

Additionally, the study finds that the reason why in particular the practices of dishwashing, laundering and EV charging are time shifted also relates to the fact that these practices involve the use of technologies that semi-automate some of the activities. Thus, the timing of the electricity consumption and the bodily involvement in practices are partly decoupled, which makes it easier to time shift the activities (e.g. postponing dishwashing to the night hours).

Also, the results indicate that static time-of-use pricing schemes (like the Dynamic Network Tariff tested in DNT) are much easier for households to "learn" and "adapt" their everyday practices to in comparison with real-time

time-of-use pricing (which the participants were also offered). To follow the real-time prices was perceived as too time demanding as this would require developing an entirely new practice of consulting day-to-day price information and continuous planning of daily practices. This indicates that there are strong benefits of static time-of-use pricing (compared with real-time pricing) because of its simplicity and because it is possible to develop new daily habits and routines, like washing the clothes during the night, which can be incorporated into the temporality of everyday life.

In addition to the above results and observations about the temporal implications of time-of-use pricing, the study also explored the spatial and material implications of time-shifting daily practices, reported in Christensen & Friis (2016). The implications of the materiality and spatial layout of the home are seldom recognised by studies of smart grid solutions, but do nevertheless play an important role. For instance, the noise from dishwashers and washing machines can keep people from postponing dishwashing and clothes washing to the night hours as this disturb their night sleep. Thus, the layout and placing of rooms in the home can have significant influence on the likeliness of getting people to time-shift their electricity consumption. Also, this indicates that the current smart grid demand-side management solutions are primarily designed for detached single-family homes with a large floor space, while it is less probable that noise-making activities can be time shifted to night hours in apartment blocks with close-living neighbours.

4.4 Interventions in mobility practices

The WP3 study also looked into the reasons for the low uptake and non-adoption of EVs. This was based on the initial observation of the missing connection between the slow uptake of EVs (and the EV test drivers' general rejection of the idea of buying an EV after the trial) and, on the other hand, the claims of the EV operator about the EVs ability to meet car drivers' needs.

The EV operators' statistical analysis showed that EVs should be able to cover about 99% of the driving needs of the TEV participants. However, the qualitative study of the participants' own perspective in WP3 shows a different picture. None of the participants wanted to acquire an EV themselves – mainly due to their experience of the tested engines being incompatible with their everyday transport practices because of limited driving range, lower comfort and security and a high purchase price.

The WP3 analysis (reported in Friis, 2016) demonstrates the need to go beyond existing assumptions about EV adoption. First, the analysis illuminates the mobility operators' strategy to increase adoption. This analysis is inspired by Spurling and McMeekin's (2014) conceptualisation of three cross-cutting practice dynamics for successive intervention in mobility patterns. They developed three alternative practice-aligned framings for the successive intervention in mobility patterns: 1) recrafting practices, 2) substituting practices and 3) changing how practices interlock. The WP3 study shows that the intervention by the Danish EV operator to some extend tried to "re-craft" and "substitute" conventional driving practices, but failed to consider how practices interlock, which our study finds to be fundamental for sustainable transition.

The design of the TEV trial did not challenge the test drivers' existing practices related to their daily transport and how these practices interlock. Instead, the operator sought to convince the TEV participants that the EV would meet their existing and future mobility demand. By highlighting the EV's competiveness on the market, the operator did not recognize how driving practices are usually performed in order to accomplish the performance of other practices such as work and leisure activities, grocery shopping etc. The following quote from the focus groups illustrates how car mobility involves a complexity of interlocked practices and activities and how the limited battery capacity (both with regard to driving range and amount of energy for heating of the cabin) creates experiences of inconvenience and lack of comfortability:

> All these thoughts of logistics. I can't drive as far as I need for fulfilling the things that I have planned in my everyday life (…) I have to think much more about my transportation. I have not had the spontaneity to take a detour when someone calls me on the road, and things like that. All the time I had to plan, Oh, all right, what am I going to do today? What car should I take? I am simply used to expect that the car is not something to think about, right. It's just there and simply has to run. It has been way too difficult thinking about these logistics… (Bella).

Another example, also showing how the daily auto mobility consists of sequences of trips related to different activities, is this:

> When I get home there are very few extra kilometres to run on, which means that you really have to consider what to do next (…) some days I had to drive home earlier from work to recharge the battery and make it ready for my evening activities. (Cevin).

Our study emphasises how EVs caused new configurations of systems of interconnected everyday practices (both temporally and spatially), which people were not prepared to accept. In particular, this was the case during wintertime due to increased energy consumption for heating the passenger compartment and low temperatures affecting the battery capacity.

Overall, the empirical results from the focus groups indicate that mobility interventions (like the one implemented by the EV operator) should recognise the system of practices (Watson, 2012) of the current (auto) mobility system. Thus, interventions should acknowledge the path dependency of practice intersections in order to change the level, scale and character of current demand. In correspondence with recent research by authors like Shove et al. (2015), Shove & Walker (2014) and Spurling & McMeekin (2014), this points to a need for new configurations of "normality" in relation to mobility and for bringing the "negotiability of demand" on the political agenda. Moreover, the analysis calls for further conceptualisations of whom, where, when and how to govern the current resource-intensive mobility practices.

Whereas the primary focus in relation to intervention has been on the strategic governance level of the TEV demonstration, the research related to WP3 has also inspired more theoretical discussions of how theories of learning and social interaction could inspire more workable designs for intervention and change of social practices related to energy consumption (Christensen, 2014).

6. Conclusions and recommendations

On basis of the research findings of WP3, summarized in Chapter 5, a number of conclusions and recommendations (policy implications) can be made.

The “techno-economic” or “techno-rational regime” is still dominating the implementation of smart grid technologies targeted households. Within this regime, electrification of the current transportation system is seen as crucial, which implies that EVs are assigned a central role for the future energy system. The mainstream assumption is to accommodate the challenge of increasing fluctuations in the energy system from renewable sources by economic incentives and technological innovation. Following this, designs and strategies are often developed without duly acknowledgement of the complexity of people’s everyday life and social practices.

The studied electric mobility intervention (TEV) only partly acknowledges the complexity of the everyday life of the participating households, and the EV operator to a large extent reproduced the widespread representation of EVs as a substitution for conventional combustion engine cars by underscoring the EV’s ability to cover existing transportation needs. In addition, the intervention draws on the economic rationality by stressing the lower operation costs of EVs.

By demonstrating how everyday habits and routines are interwoven in socio-material systems of consumption, the WP3 study suggests that smart grid operators, and other key actors, should recognise the collective nature of daily practices and how these are interrelated in “systems of practices”.

It is of course important to note that the results from our study of the TEV and DNT trials are influenced by the deficiencies of the involved technologies. Both the EVs and the charging-boxes (for the remotely controlled charging of the EVs) represent first generation mass-produced versions. This has most likely influenced the results. In particular, the participants in the focus groups (who were EV test drivers in the wintertime) experienced the EV as too unsafe, uncomfortable, inconvenient and too expensive.

The study explores the normalised habits and routines related to the energy consumption of people’s everyday life. Our analysis of the combined TEV and DNT trial showed, among other things, that most participants time-shifted their EV charging, laundry and dishwashing activities to low-tariff periods. The qualitative analysis shows that this was in particular due to the participating households’ commitment and engagement with regard to following the operators’ rules and the intentions of the trials. In comparison, economic incentives had a minor impact on developing the new practices. This shows that engagement, commitment and the experience of participating in collective action play a significant role in order to achieve time shifting.

Moreover, the temporality of the everyday life and practices of households are pivotal for the households’ flexibility of time shifting their electricity consumption. Time shifting routines and practices influence the synchronisations and interrelations between social practices and, by doing this, has a high impact on the flexibility.

The analysis of time shifting also demonstrates how social practices are interrelated and dependent on wider systems of practices partly shaped by collective and institutional rhythms and the temporalities of the households and their members. This also involves time constraints that make many everyday practices difficult to time shift (for instance the timing of dinner cooking and working hours). Hence, smart grid solutions and strategies should be aware of (and integrate) the temporalities of practices and households' everyday life (including differences between households).

The study revealed a number of unintended, negative consequences of the smart grid integration. Most alerting was that the test drivers participating in the focus groups (without a time-of-use pricing scheme) plugged-in their EVs when they came home from work. By doing this, the recharging of the EVs coincided with the critical evening load peak between 5 and 7 PM. This demonstrates the need to combine EVs with other measures/solutions (like time-of-use pricing) in order to avoid new or exacerbated peak loads and grid capacity problems. Moreover, several participants expressed that the EV increased the amount of driving trips during the trial and thus replaced bicycle rides and walking. These examples of unintended, negative consequences show exactly why it is so important to take the dynamics of everyday life and daily practices into account when planning and designing smart grid solutions and interventions.

The study also shows that the low uptake of EVs is not only about the lack of economic incentives (such as low taxes on EVs), but is also a result of the current infrastructure and systems of auto mobility being based on the combustion engine car. Auto mobility is a key example of a deeply complex and profoundly embedded socio-technical system, which requires fundamental transition that goes beyond mere technological changes in order to ensure a large-scale reduction in fossil fuel consumption. Employing a system of practices approach suggests interventions to intervene with (and challenge) the systems of practices in which car mobility is embedded. Instead of reproducing traditional approaches and understandings by focusing on technological "fixes" or trying to change people's individual behaviour through information campaigns, our analysis emphasises that reducing fossil fuels on the scale that appears to be necessary requires interventions to change the entire system of resource-intensive practices. "Unlocking" the current systems of practices requires interventions that take into account the path dependency of the present infrastructural systems of (mobility) practices and how they connect with other practices like working practices, grocery-shopping practices and leisure activities. Essentially, such ambitious interventions would bring the "negotiability of demand" on the agenda.

See also the IHSMAG publication "Recommendations and criteria for the design of smart grid solutions for households" (Christensen et al., 2016) for further policy and design recommendations developed on basis of WP3 (as well as the other WPs in IHSMAG).

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